Highlights of activities for EF08 "BSM : model specific explorations"

Jim Hirschauer, Elliot Lipeles, Nausheen Shah

Snowmass 2021 EF workshop : 22 July 2020

Brief introduction to EF08 topics

- From Alessandro's talk on Monday, July 20:

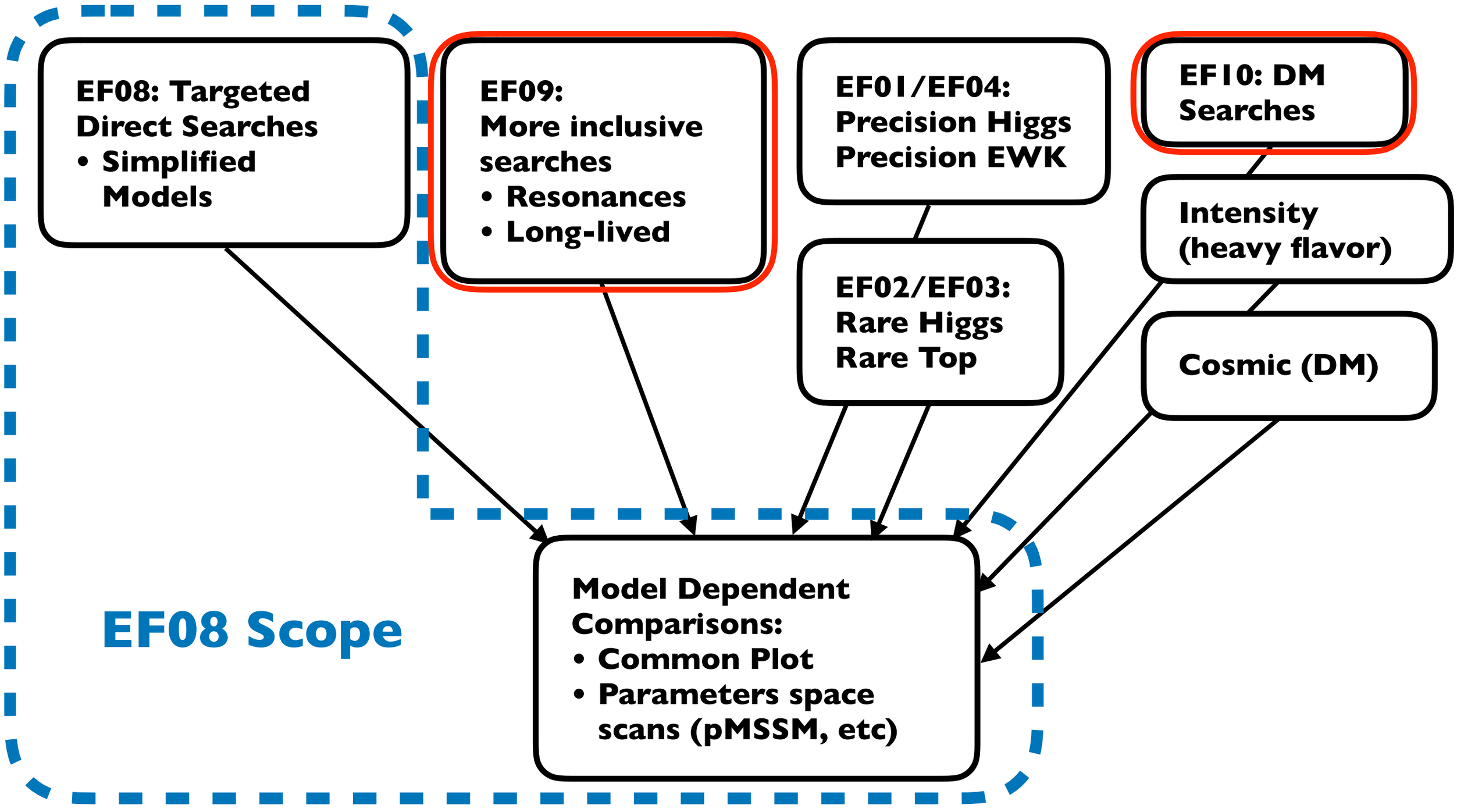
EF08 - Model Specific explorations

- SUSY, Extra Dimensions, and Leptoquarks etc. + Composite Higgs
- Sensitivity, Reinterpretations of sensitivities (e.g. a long-lived particle as a Higgsino)
- Model parameter scans and comparisons with precision measurements (e.g. pMSSM scans)
    a. SUSY: Strong (inclusive searches / gluino / squark), 3rd gen (stop, sbottom), EWKino, singlino, “Pure” higgsino, R-parity violating SUSY
    b. Blackhole Mulitjets, RS Gravitons
    c. pMSSM or other scans
    d. Model-specific searches for excited fermions

Please submit your informal and non-binding **expression of interest** today!

https://docs.google.com/forms/d/e/1FAIpQLSf2bUmPbFVrTsDK50x7iMKtMNbImRcH0qHzomrmH1Tg5bAp8w/viewform

EF08 interaction with other TG and Frontiers



Please submit your informal and non-binding **expression of interest** today!

https://docs.google.com/forms/d/e/1FAIpQLSf2bUmPbFVrTsDK50x7iMKtMNbImRcH0qHzomrmH1Tg5bAp8w/viewform

Recent meetings

- May 28 : Kick-off meeting with report on SUSY studies from European Strategy process
- June 11 : Composite Higgs
- June 25 : R-parity conserving SUSY
- July 7 : Preparatory Joint BSM TG session with EF02+07+09+10
    - **Manimala Chakraborti, Heinemeyer**, Saha: Muon g-2 and SUSY MSSM scans
    - **Rahool Barman**: Light neutralino dark matter in NMSSM

- Aug 6 : Next meeting, topic TBD

Find meetings and (email list subscription) here

https://snowmass21.org/energy/bsm_models

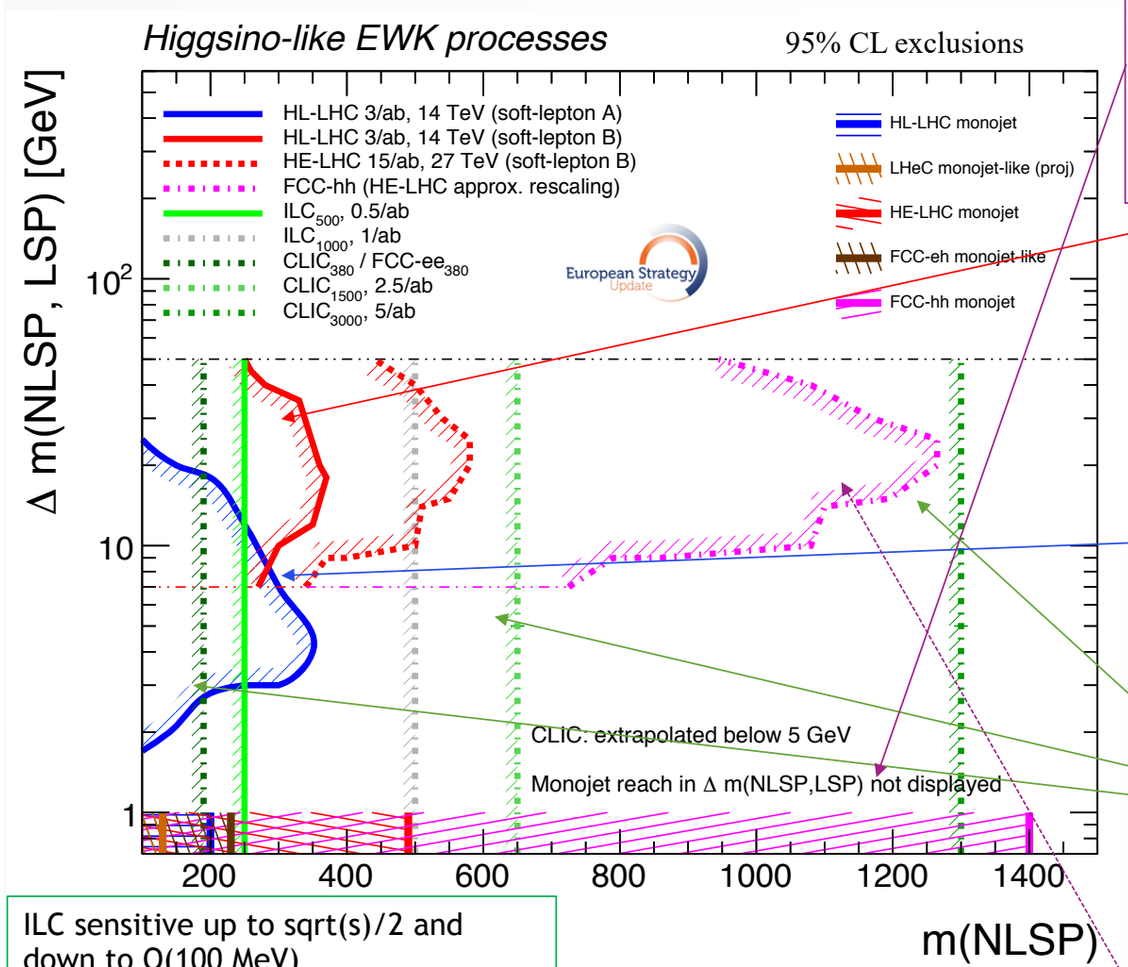
Please submit your informal and non-binding **expression of interest** today!

https://docs.google.com/forms/d/e/1FAIpQLSf2bUmPbFVrTsDK50x7iMKtMNbImRcH0qHzomrmH1Tg5bAp8w/viewform

SUSY for European Strategy

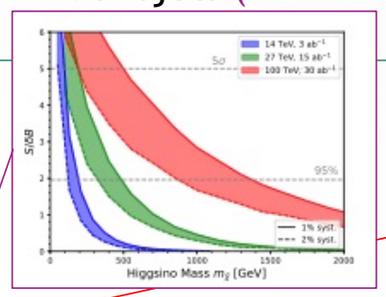
- **Monica D'Onofrio gave excellent summary of SUSY studies for ES update** with invaluable summary of lessons learned ➔ EF08 will build on ES work.
- Examples of **lessons learned** for **higgsino-like EWKino processes**:
  - Decide early on **coherent set of model assumptions**.
  - Need **dedicated FCC-hh studies** ➔ ES used extrapolations.
  - Need **reinterpretation of hadron collider monojet analyses as function of higgsino Δm** for Δm=1-20 GeV, especially for complementarity with lepton colliders ➔ in coordination with EF10.

Higgsino-like EWK processes

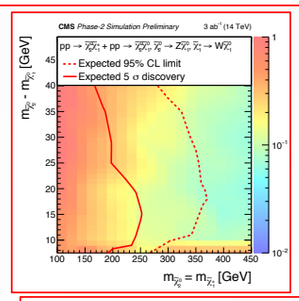


ILC sensitive up to sqrt(s)/2 and down to O(100 MeV)

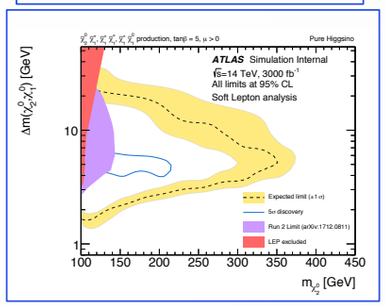
Monojets (HL/HE/FCC-hh/LHeC/FCC-eh)



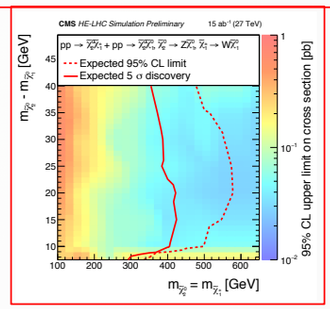
HL-LHC soft lepton analysis CMS

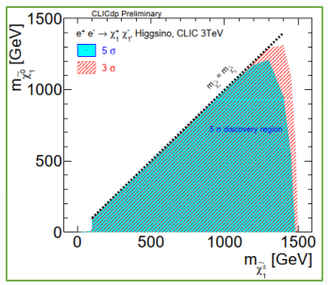


HL-LHC soft lepton analysis ATLAS



HE-LHC soft lepton analysis





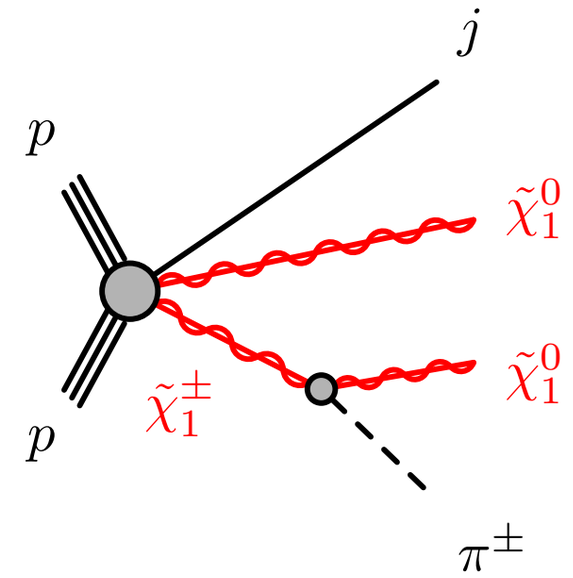
CLIC 3 TeV, results rescaled also for CLIC1.5, CLIC380, FCC-ee **(tbc)**
Analysis done for DM(NLSP,LSP)=5 GeV - below: extrapolated

Indicative partonic rescaling of HE for FCC-hh soft-lepton

Physics Briefing Book
CERN-ESU-004

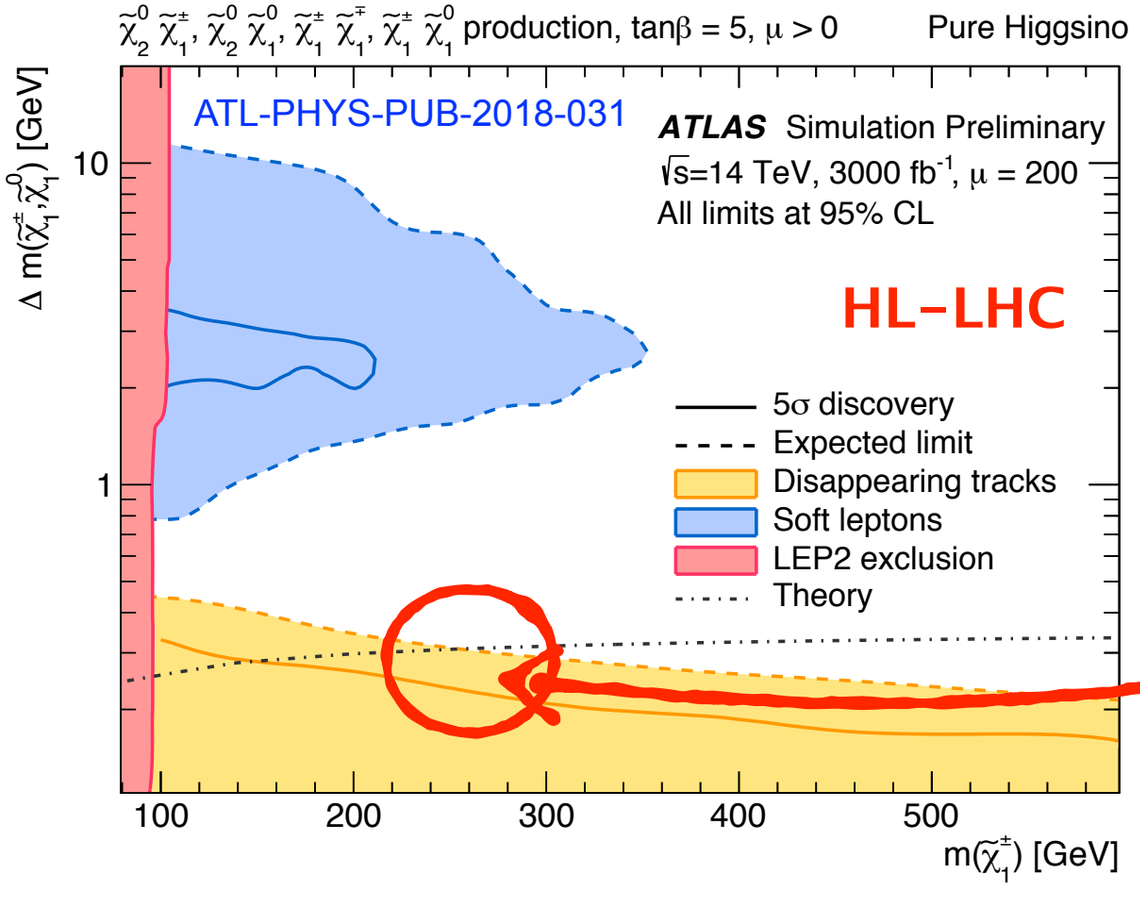
SUSY for European Strategy (II)

- Lessons learned for **pure higgsino search with disappearing tracks:**
  - **Review assumptions made for fake backgrounds** for ATLAS HL-LHC study
  - Incorporate **CMS HL-LHC study**
  - FCC-hh sensitivity based on Delphes detector simulation with detector design similar to LHC ➔ **update with more realistic FCC-hh detector**

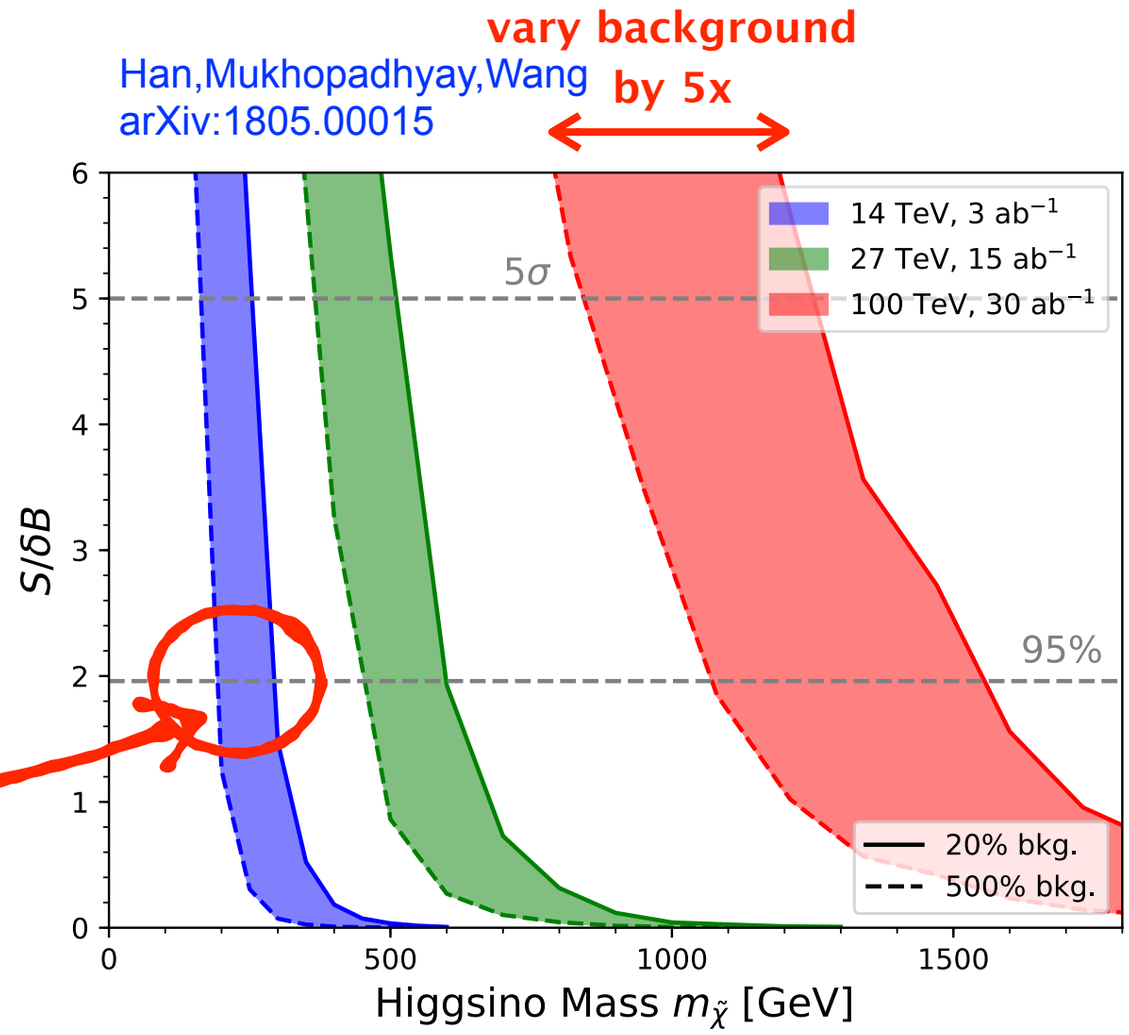


- Careful treatment of detector simulation is obviously critical.
- Analysis coordinated by EF09 with SUSY interpretation by EF08.

Report on BSM at HL/HE-LHC, arxiv:1812.07831



Han,Mukhopadhyay,Wang
arXiv:1805.00015



Composite Higgs

Inspiring overview from M. Peskin:

The why problem of Electroweak Symmetry Breaking is still the most important problem in particle physics.

SUSY and similar models of EWSB no longer have pride of place. We need to seriously investigate the idea that the Higgs boson is composite, with new strong interactions at 10-50 TeV.

Composite Higgs signatures from G. Cacciapaglia:

- Focus on **beyond-minimal top partners**
  - e.g. exotic cascade decays of charge 5/3 top partner through BSM states lighter than $X_{5/3}$
- Inspired excellent discussion on complementary needs for
  - vanilla / **minimal benchmark models**
  - **novel benchmark models** that can help elucidate differences in reach for various collider/detector scenarios

Xie Ke-Pan et al, 1907.05894

Cascade decays			after t and τ decay
$X_{5/3}$	tW^+	–	$(bW^+)W^+$
	$\bar{b}\pi_6$	$\bar{b}tt$	$\bar{b}(bW^+)(bW^+)$
	$t\phi^+$	$tW^+\gamma,\ tW^+Z$	$(bW^+)W^+\gamma,\ (bW^+)W^+Z$
		$tt\bar{b}$	$(bW^+)(bW^+)\bar{b}$
		$t\tau^+\nu$	$(bW^+)(W^{+*}\bar{\nu})\nu$
	$b\phi^{++}$	bW^+W^+	bW^+W^+
		$bW^{+(*)}\phi^+$	$bW^{+(*)}W^{+(*)}+X$
		$b\tau^+\tau^+$	$b(W^{+(*)}\bar{\nu})(W^{+(*)}\bar{\nu})$

R-parity conserving SUSY

Comprehensive overview and status from C. Wagner:

- We are just starting to constrain the region of stop masses consistent with the MSSM Higgs mass determination !
- No clear deviation of Higgs coupling from SM expectations : Alignment or Decoupling ?
- There is still clear room for discovery at the LHC. → **and future colliders**

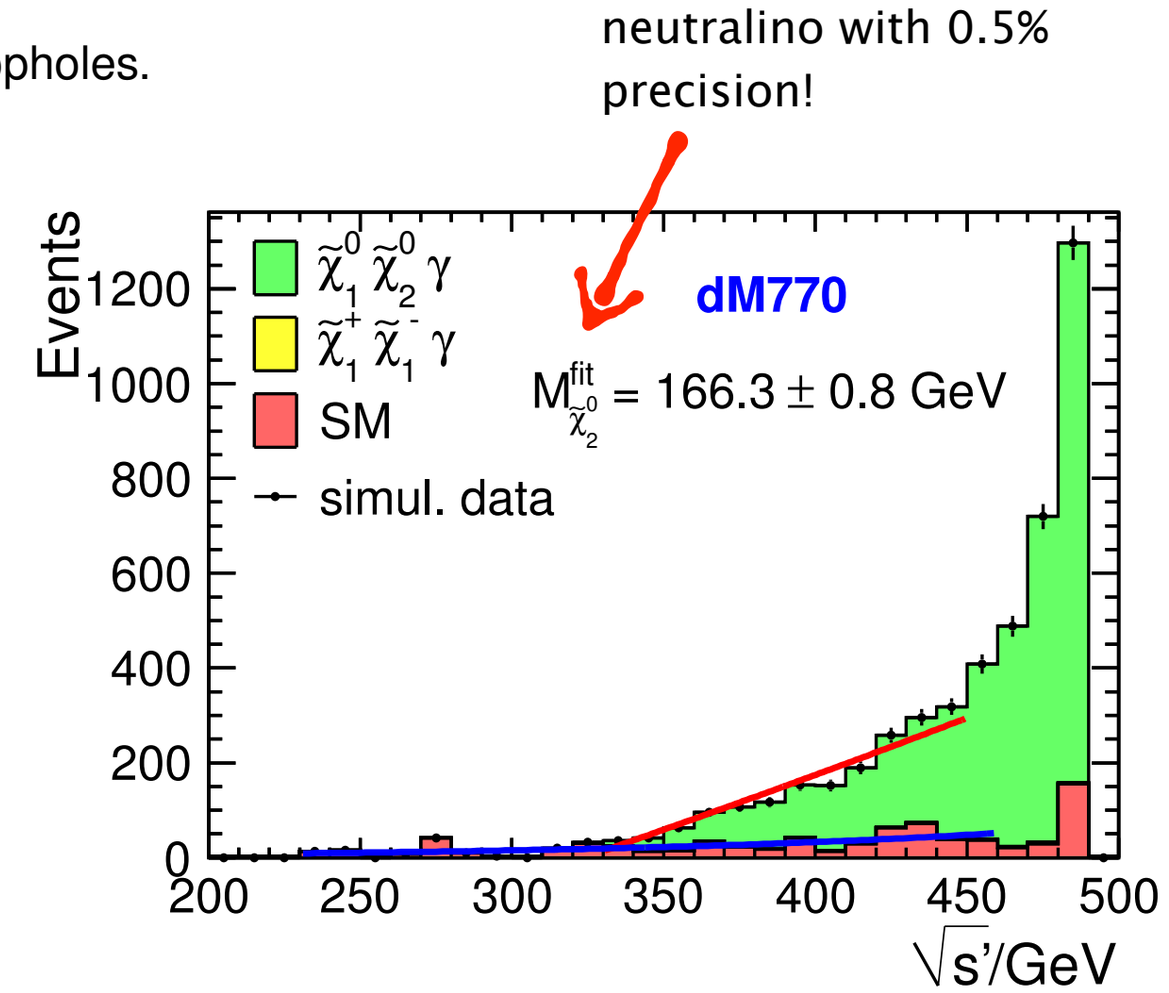
ILC perspective on SUSY from M. Berrgren

- Future pp machines have
  - discovery potential to very high masses
  - but - to put it bluntly - NO exclusion potential: always loopholes.
- Future TeV-scale ee machines have
  - Full discovery and exclusion potential up to the kinematic limit

Status of ILC SUSY studies

- RPC MSSM covered well
- More work needed for
  - RPV SUSY
  - Long-lived particles
  - NMSSM

Reminded us lepton colliders allow high precision measurements of SUSY parameters, e.g. mass of 167 GeV neutralino with 0.5% precision!



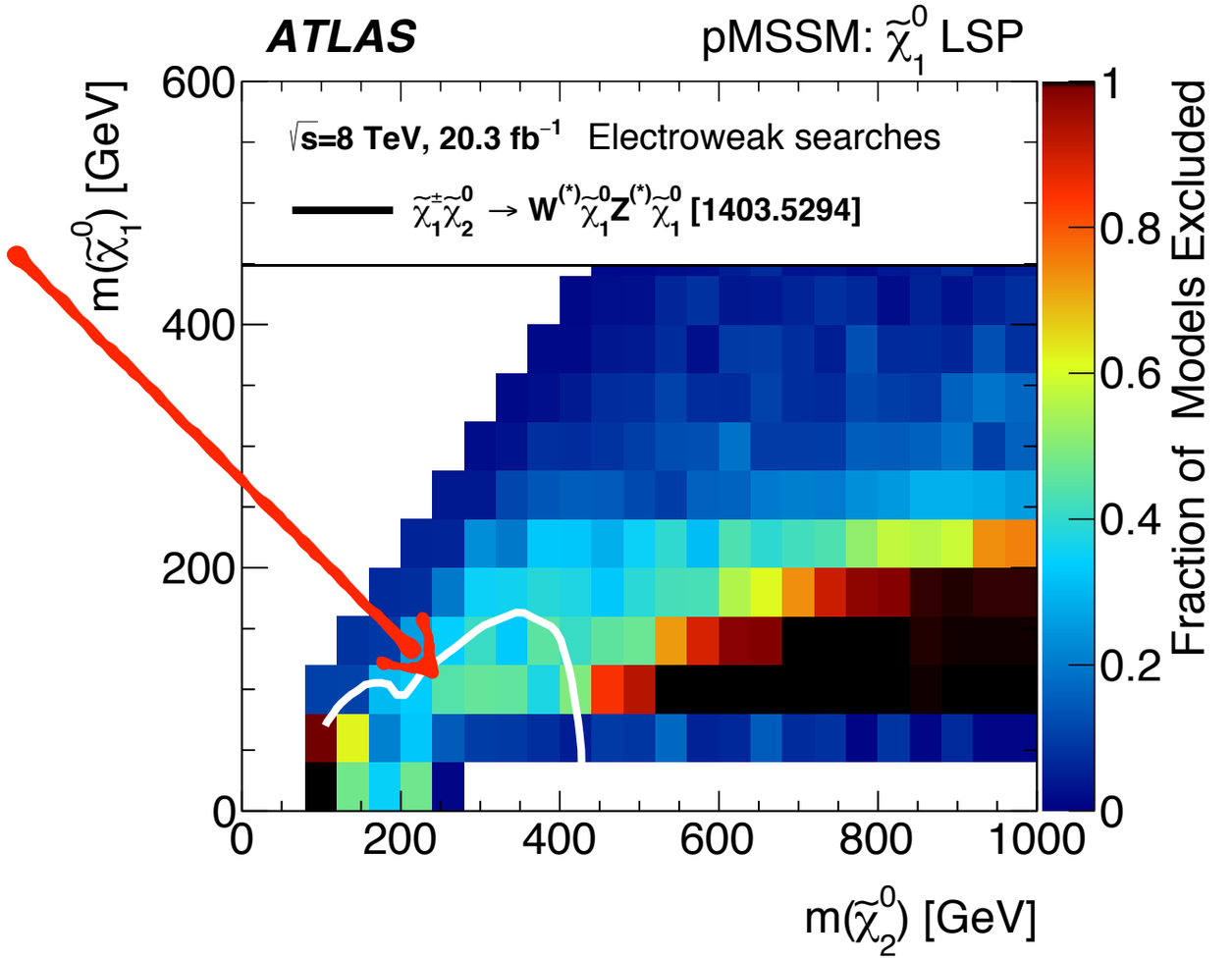
R-parity conserving SUSY (II)

pMSSM scans from S. Bein (CMS) and discussion from Giordon Stark (ATLAS) et al.

- **Going beyond 2D simplified models (SMS)** is recurring theme of EF08 activities
  - see yesterday's excellent discussion led by **Suchita Kulkarni**
  - SMS can omit critical **dependence of sensitivity on parameters** of the full model not included in the SMS (other masses, branching fractions, etc)
  - some simplified models are not plausibly realized in full model

- Use **interpretations of search results in scan of 19-parameter phenomenological MSSM** to help
  - identify regions where SMS fail to capture whole picture
  - design beyond-SMS summaries to show features not included in SMS plots.
  - will complement SMS summaries.

ATLAS, arXiv:1508.06608



Near term plans and meeting topics

(1) **R-parity violating SUSY**.

(2) **Extra dimensions**.

(3) Concrete plan for how to use **naturalness** responsibly in EF08 summaries

- building on **Raman Sundrum's thought provoking talk** from yesterday

(4) Continue inviting groups that have submitted **Expressions of Interest** to present plans

(5) In coordination with community, start converging on **concrete (but evolving) plans** for

(a) set of **summary plots** and **benchmark models** (building on work for ES update)

(b) necessary **dedicated analyses**

(c) necessary **reinterpretations** of work from other EF TG and Frontiers

- e.g. EF09 (LLP), EF10 (mono-X), EF1-4 (precision measurements)

(d) **new ideas**!

(e) **match Expressions of Interest** to (a)-(d)

Next meeting is Thursday, August 6, at 11am EDT.

Find meetings and (email list subscription) here
https://snowmass21.org/energy/bsm_models

Please submit your informal and non-binding **expression of interest** today!
https://docs.google.com/forms/d/e/1FAIpQLSf2bUmPbFVrTsDK50x7iMKtMNbImRcH0qHzomrmH1Tg5bAp8w/viewform